PRETTY: Cubesat for precise altimetry using navigation satellites

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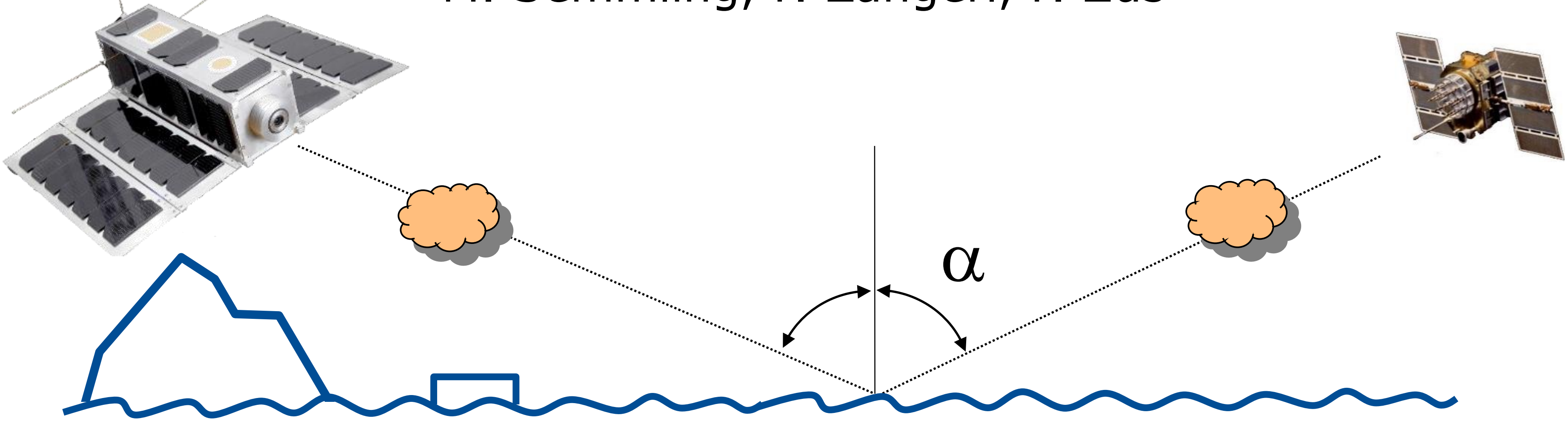
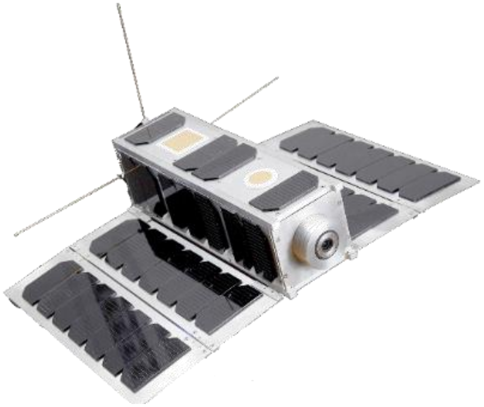
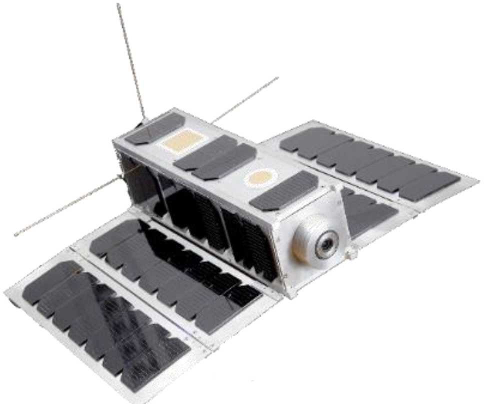




What is PRETTY?

- Small satellite, cubesat (10*10*30cm³)
- ESA mission, consortium led by RUAG (H. Fragner)
- GNSS-Reflectometry and Space Weather
- Precise altimetry using grazing geometries
- Unique: Direct correlation of direct and reflected GNSS signals
- Launch expected for 2021

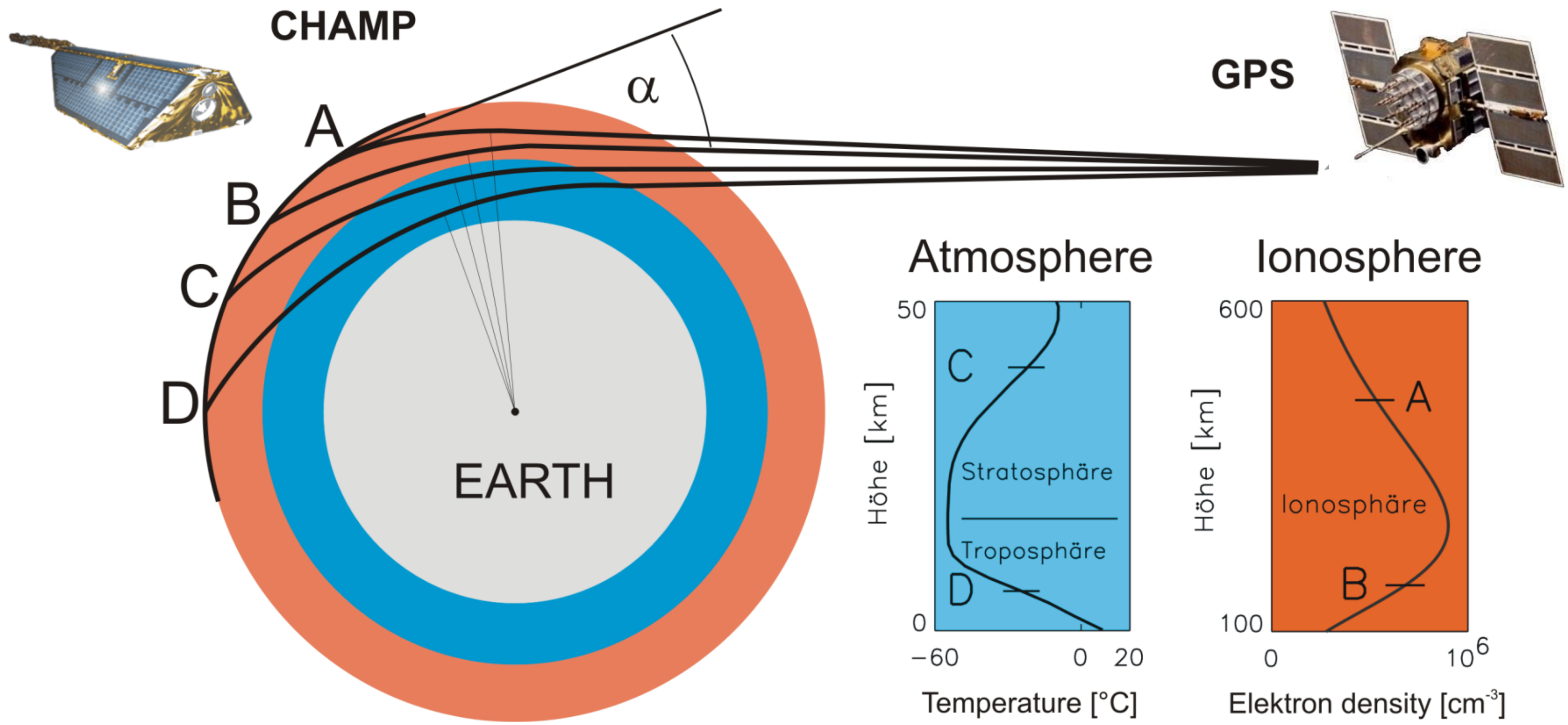


What I can talk about? (not yet in-orbit data)

- Some background and motivation
- Some information on satellite and mission status

CHAMP: A quite successful GPS radio occultation mission

GNSS radio occultation



Wickert , 2002

Key properties: global coverage, all-weather, calibration free, very precise, high vertical resolution

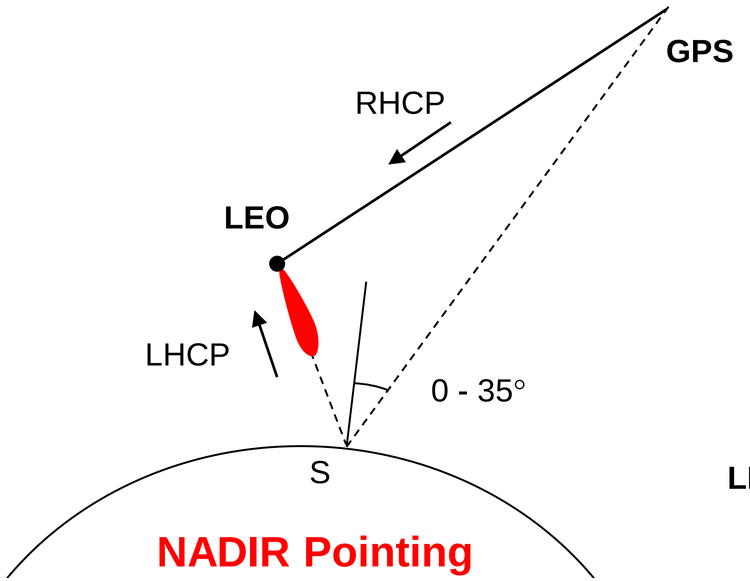
Very attractive for weather forecast, Climate and atmospheric research

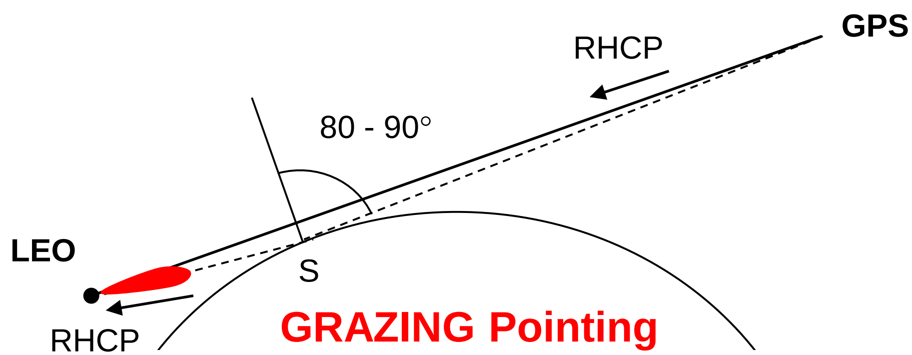
CHAMP had additional antenna: LHCP nadir

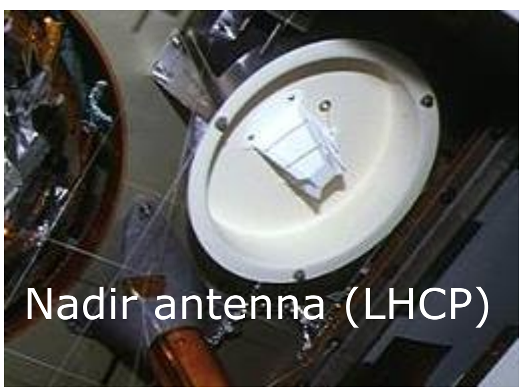
NADIR pointing receiving antenna: scatterometry, altimetry

GRAZING pointing receiving antenna: radio occultation, altimetry

Thanks: M. Martin-Neira





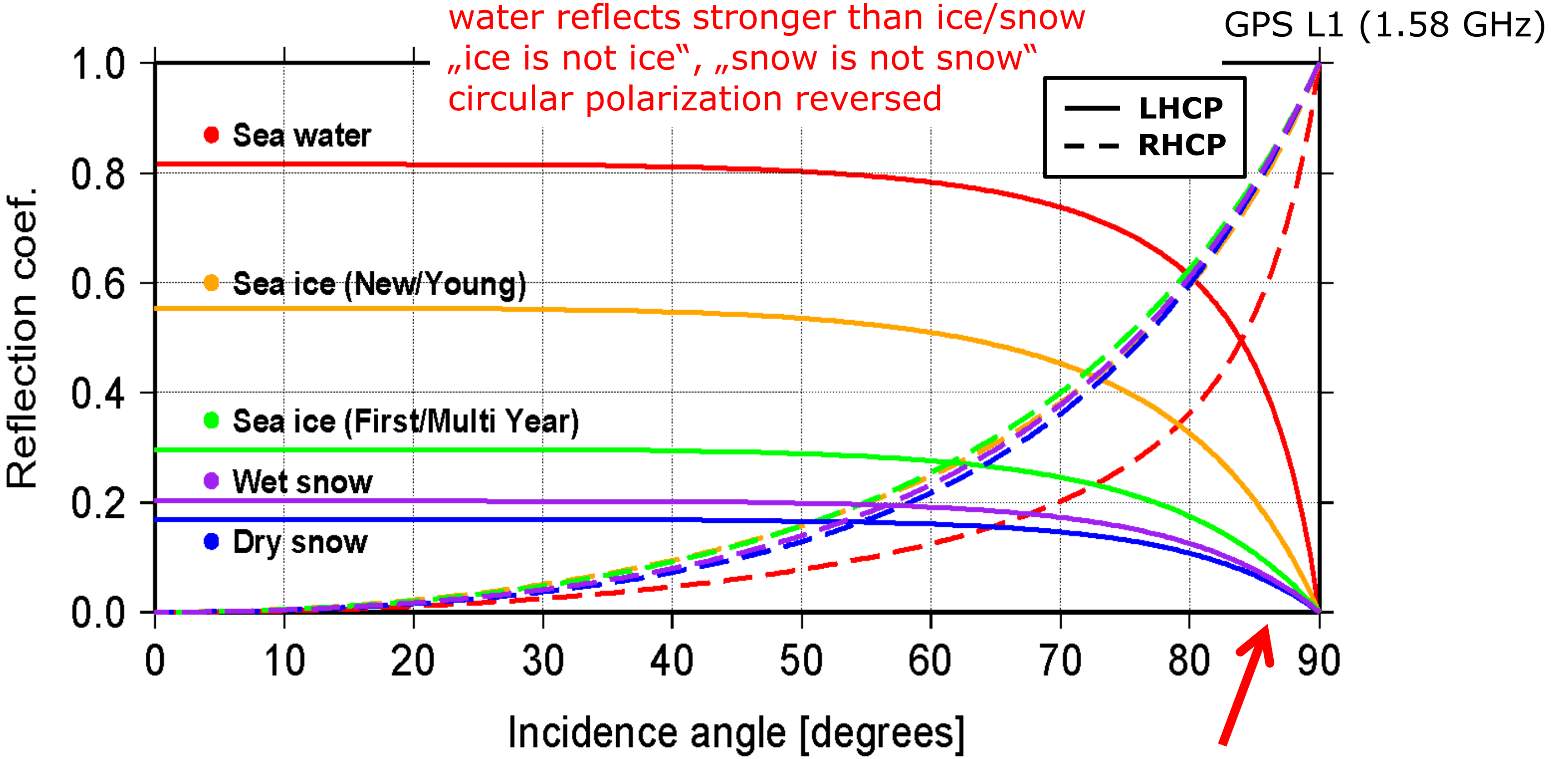


Reflection coefficient r

$$r = \frac{R^2}{E^2}$$

R, E – Amplitudes of reflected and incoming waves

water reflects stronger than ice/snow
„ice is not ice", „snow is not snow"
circular polarization reversed



at low elevations also significant RHCP contribution
here stronger signals for ice/snow compared to water
polarization same as for incoming signal

Thanks F. Fabra

Prof. Alexander Pavelyev (1938-2018)

BISTATIC RADAR AS A TOOL FOR EARTH INVESTIGATION USING SMALL SATELLITES

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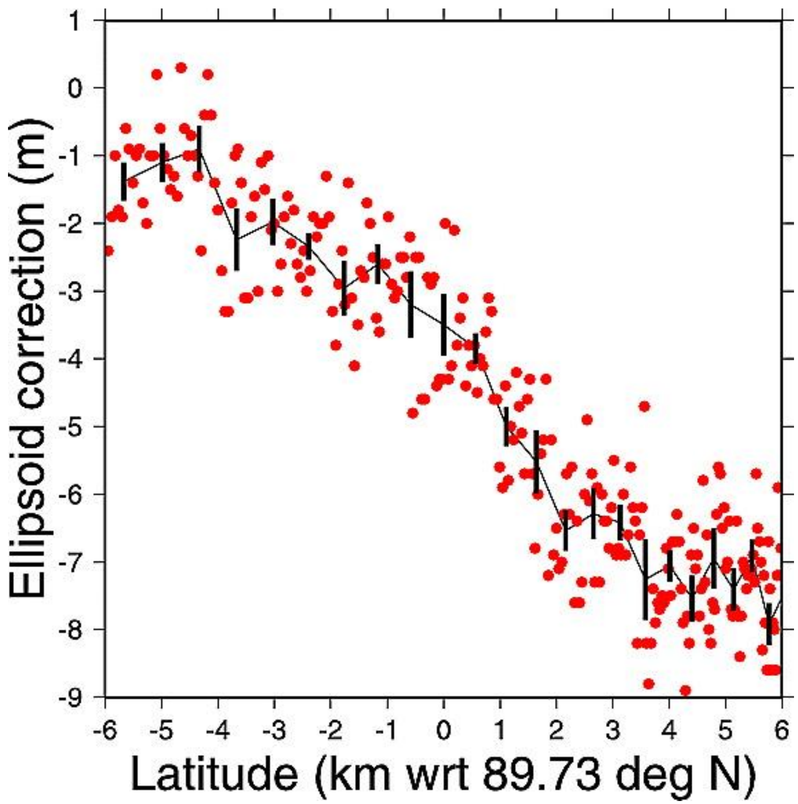
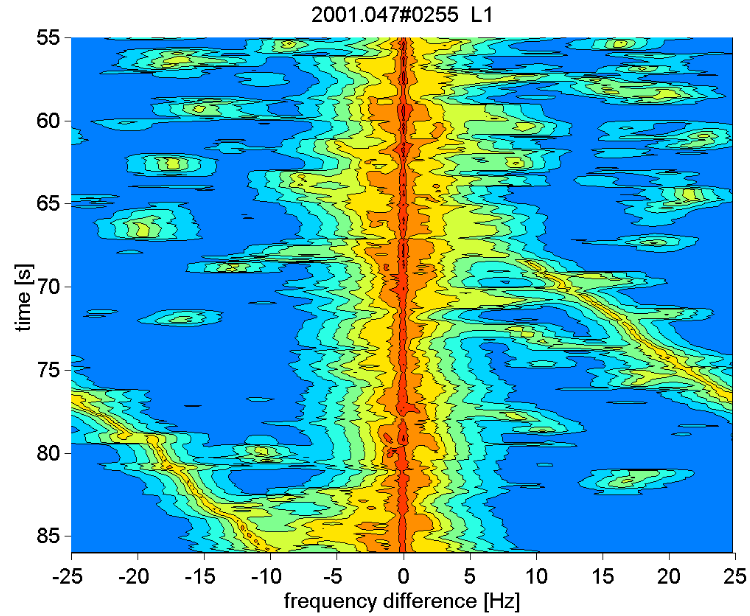
Institute of Radio Engineering and Electronics of Russian Academy of Sciences (IRE RAS)
1, Vvedenskogo Sq., Fryazino, 141120, Russia

Acta Astronautica 1996

Coherent reflections observed by CHAMP



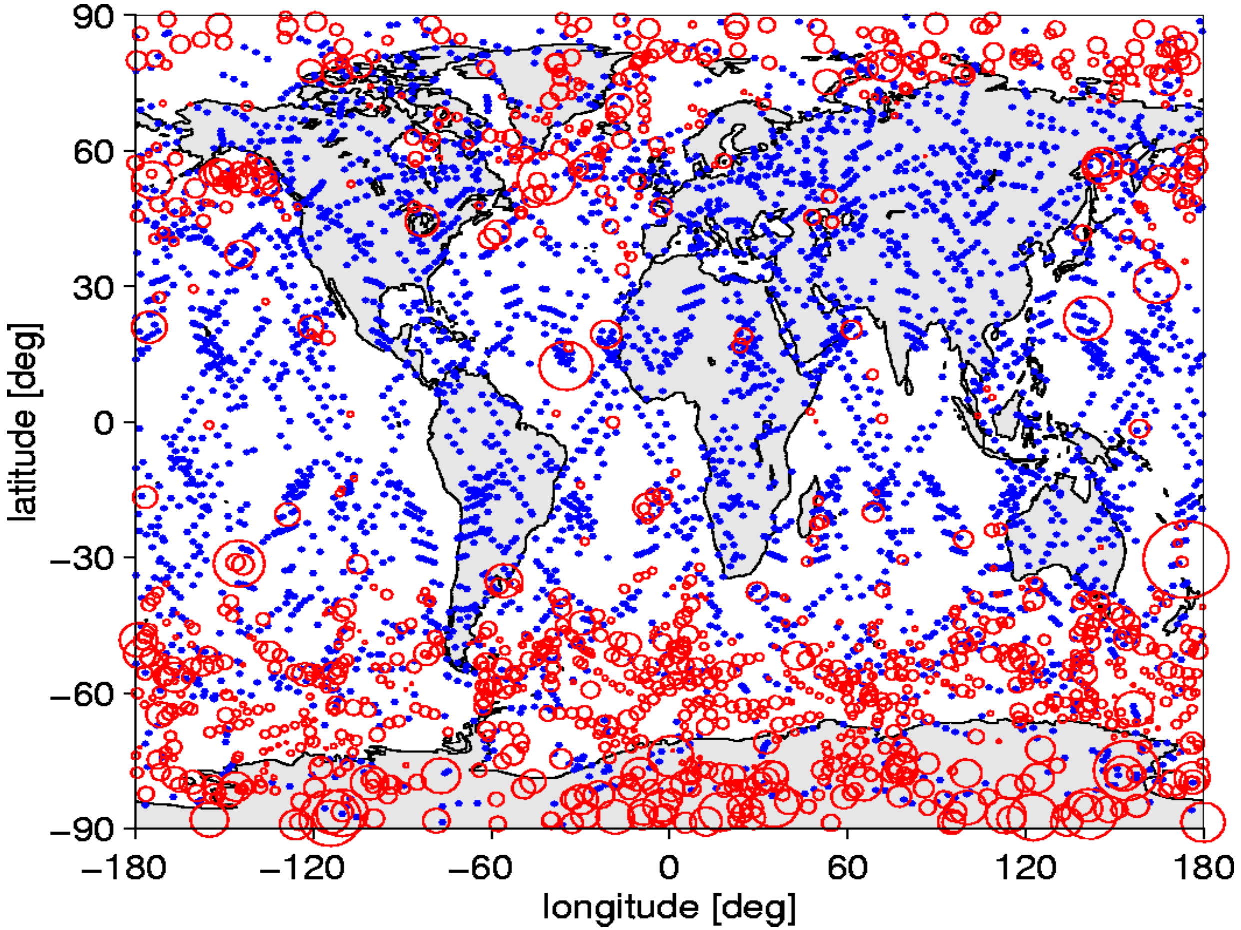


signatures of coherent reflection in CHAMP occultation data

- Topographic ice-profile at North-Pole
- 70 cm precision, ~ 1 km horizontal sampling

Cardellach et al., 2004
Beyerle et al., 2002

Global distribution of reflection events (CHAMP)



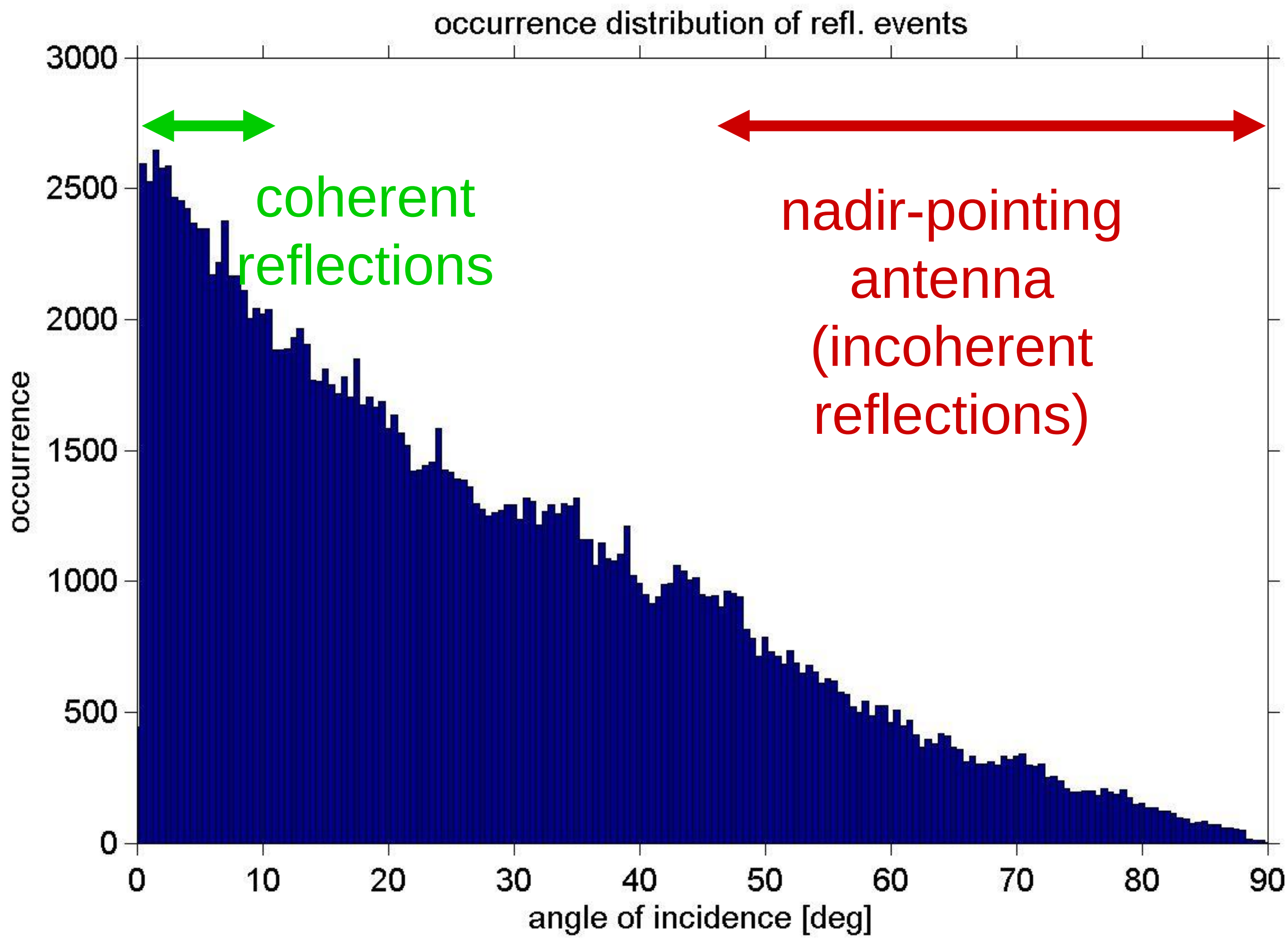
red Reflection **blue** Occultation w/o reflection

Beyerle et al., 2002

Scatterometry / Reflectometry

	Scatterometry (incoherent refl.)	**Reflectometry** (coherent refl.)
observables	altimetric height significant wave heights wind speed & direction	altimetric height
sensitivity w.r.t. tropo- & ionospheric disturbances	moderate	high
antenna	high-gain (small field-of-view)	low-gain (large field-of -view)
data volume	high	moderate

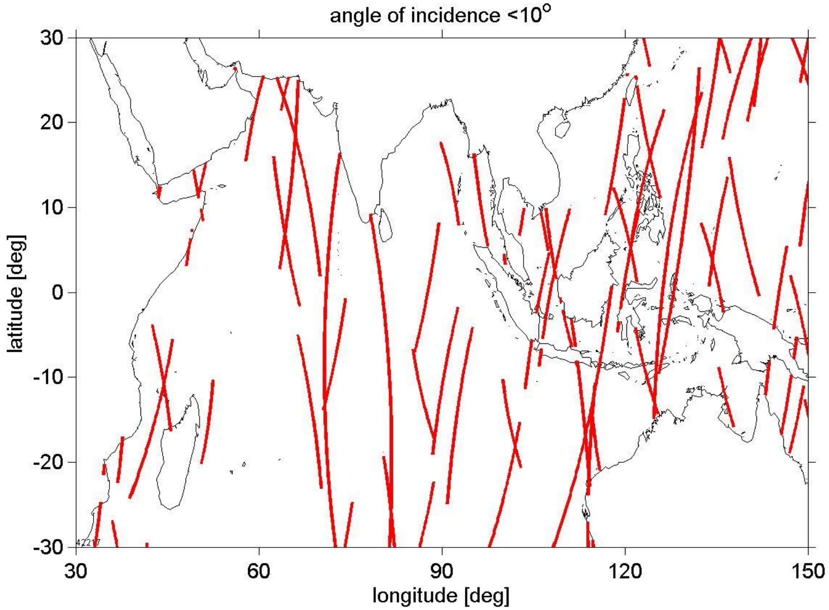
Simulations: 10 sat, CHAMP, 100 min



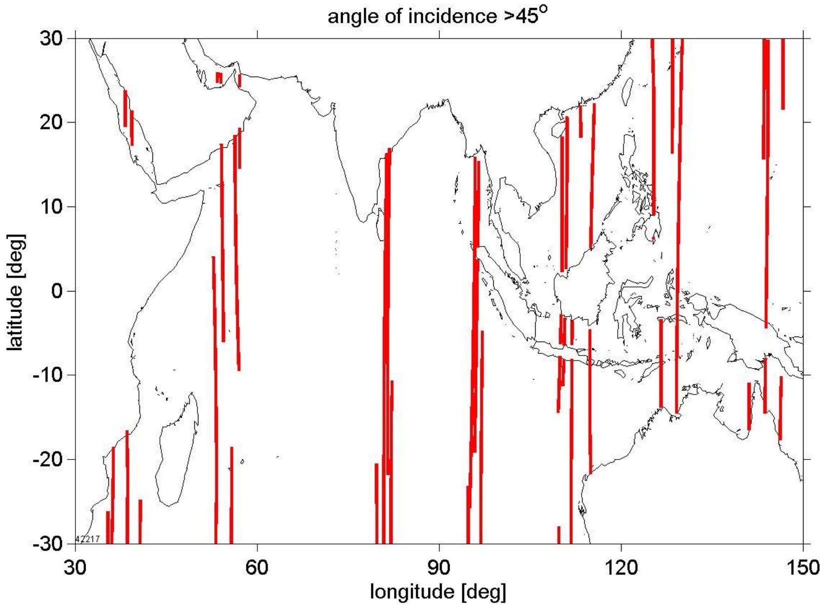
Thanks: R. Stosius/G. Beyerle

Simulations: CHAMP-like constellation

Coherent (i < 10°)



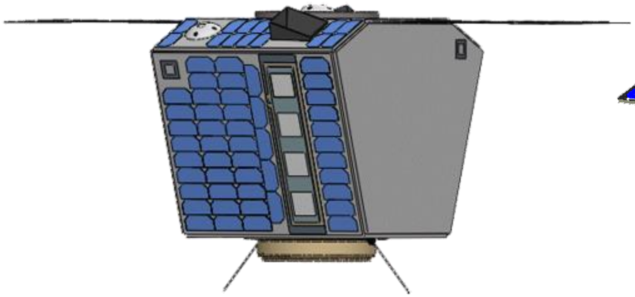
Incoherent (i>45°)

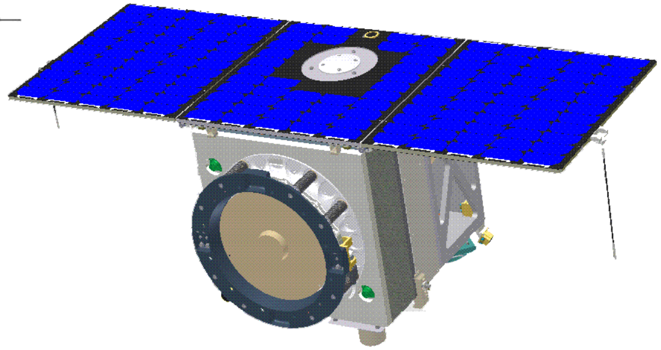


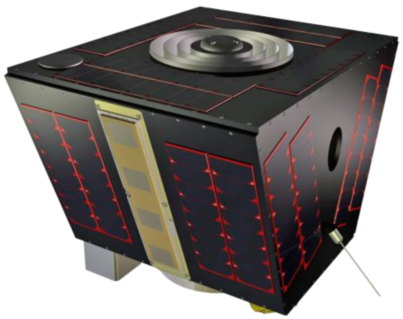
Thanks: R. Stosius/G. Beyerle

Astro- und Feinwerktechnik Adlershof GmbH

Small satellite missions: Phase A studies (part of GITEWS)



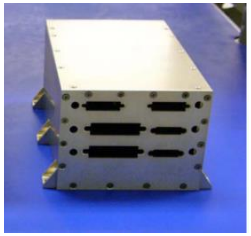




MicroGEM, 2009 (~130 kg)

NanoGEM, 2012 (~50 kg)

NanoX, 2012 (~50 kg)

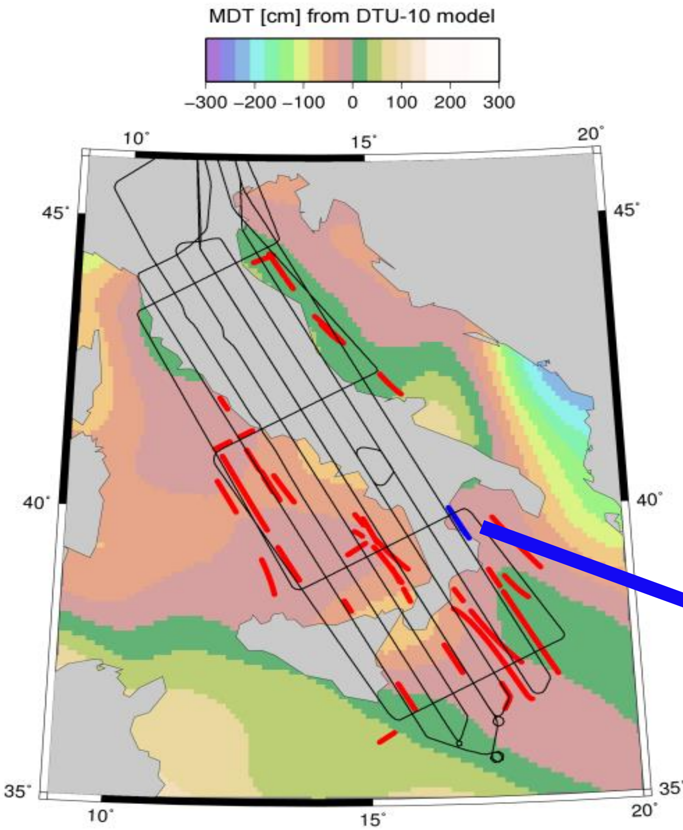


Pyxis

Javad/Triumpf

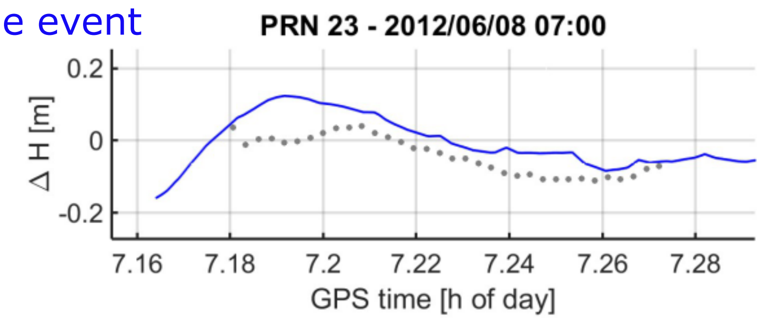
Javad/Triumpf

Airborne campaign for altimetry



Helmholtz research aircraft HALO.

Example event

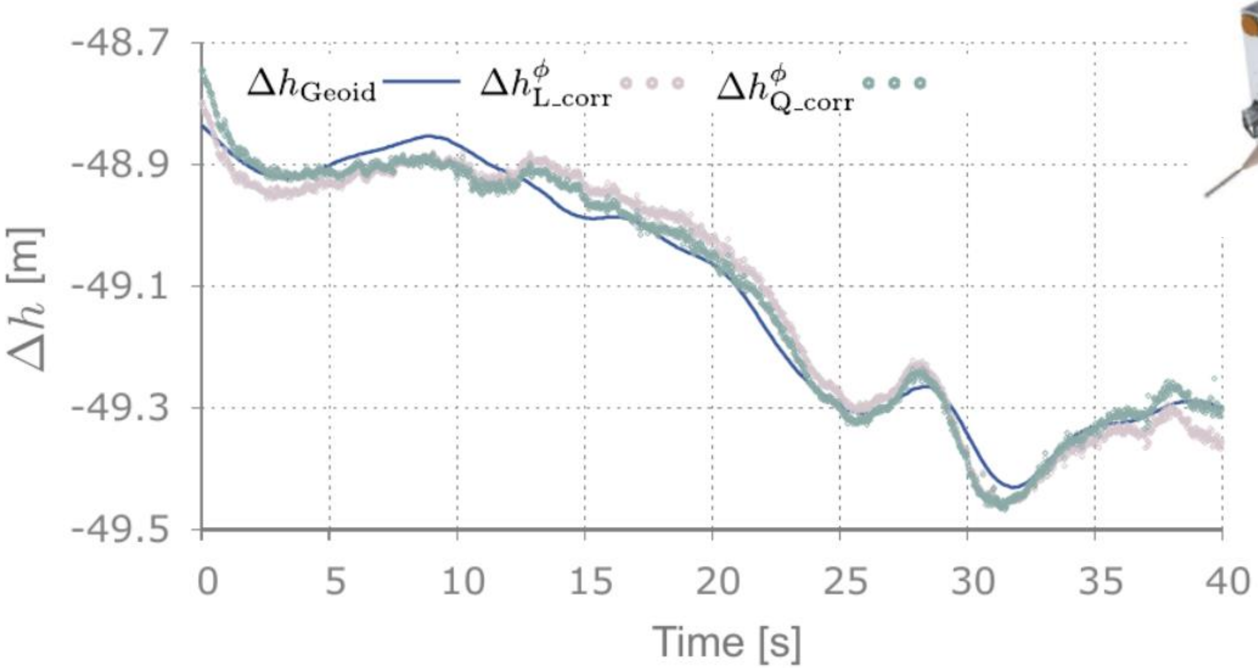


Ground tracks in the Mediterranean region between June 6 and 12, 2012.

Comparison of relative topography from GNSS-R observations (grey dots) with the Mean Dynamic Topographic model (blue line).

Semmling et al., 2014

Altimetry with real data



- GNSS-R phase delay altimetry over Hudson Bay sea ice (TDS-1 at ~50 deg incidence in raw sampling and processed on ground).
- Dots: altimetric retrievals at 20 msec sampling using two different sets of corrections; Solid line: Canadian Geodetic Vertical Datum local geoid 2013.
- RMS differences with the geoid are 2.6 and 3.5 cm

Li et al., 2017

GNSS-R with interferometric and clean replica approach

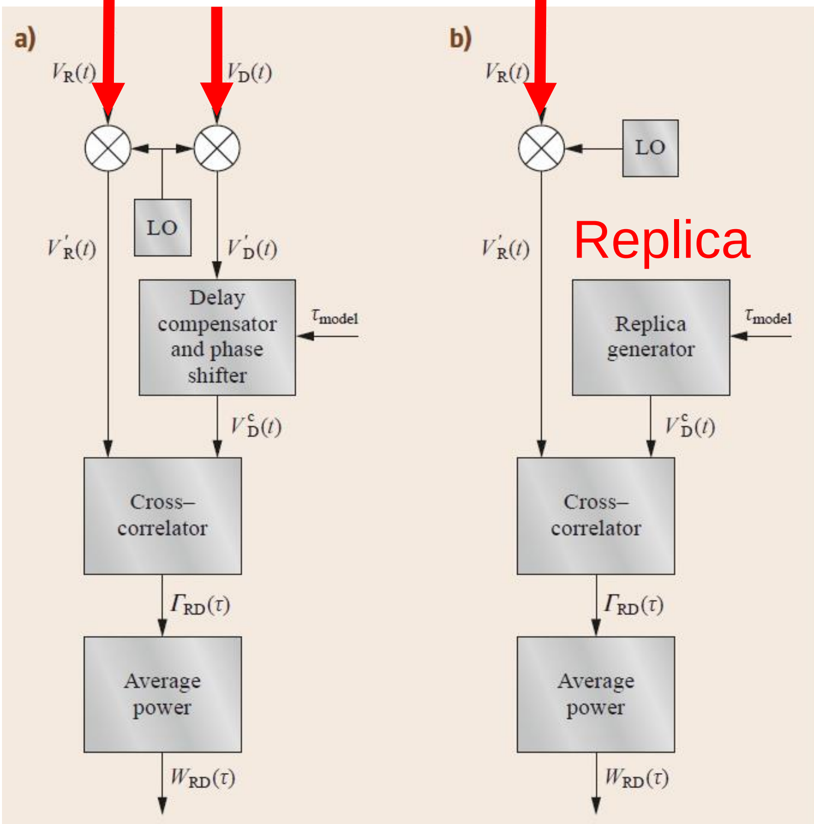
Interferometric/Clean Replica approach

Reflected

Direct

Reflected

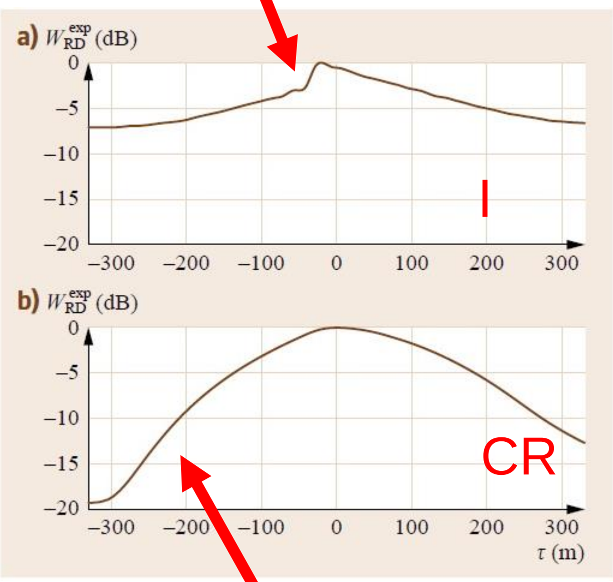
Replica



Also signals with unknown codes can be used (I)

Waveforms from flight exp. h=3 km, simultaneously with I and CR

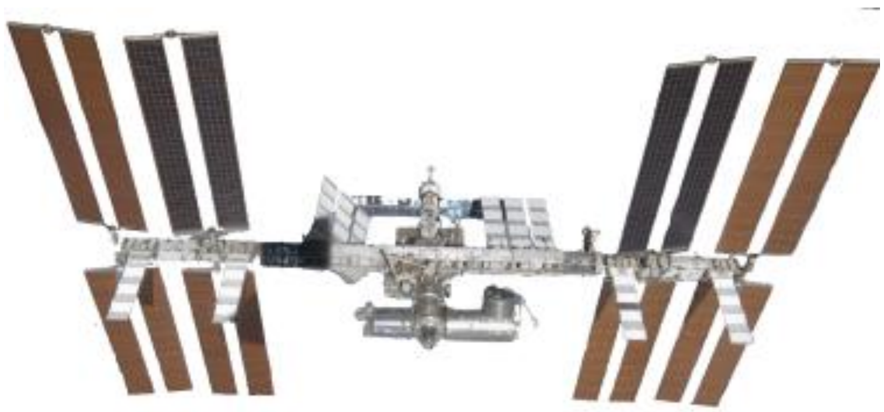
Steeper slope of waveform

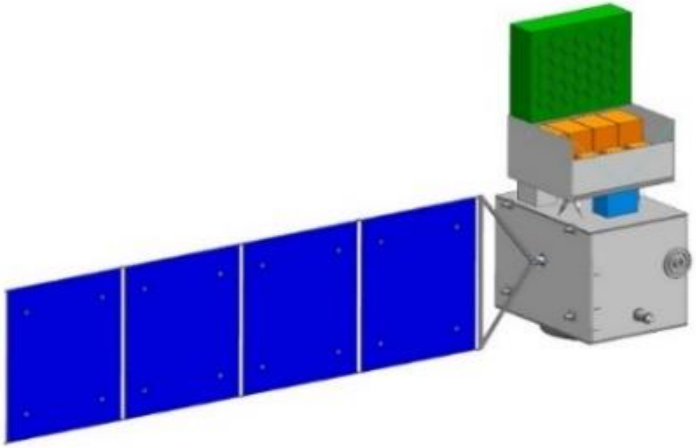


Higher dynamic range

Rius/Cardellach 2017

GEROS-ISS and G-TERN (ESA)



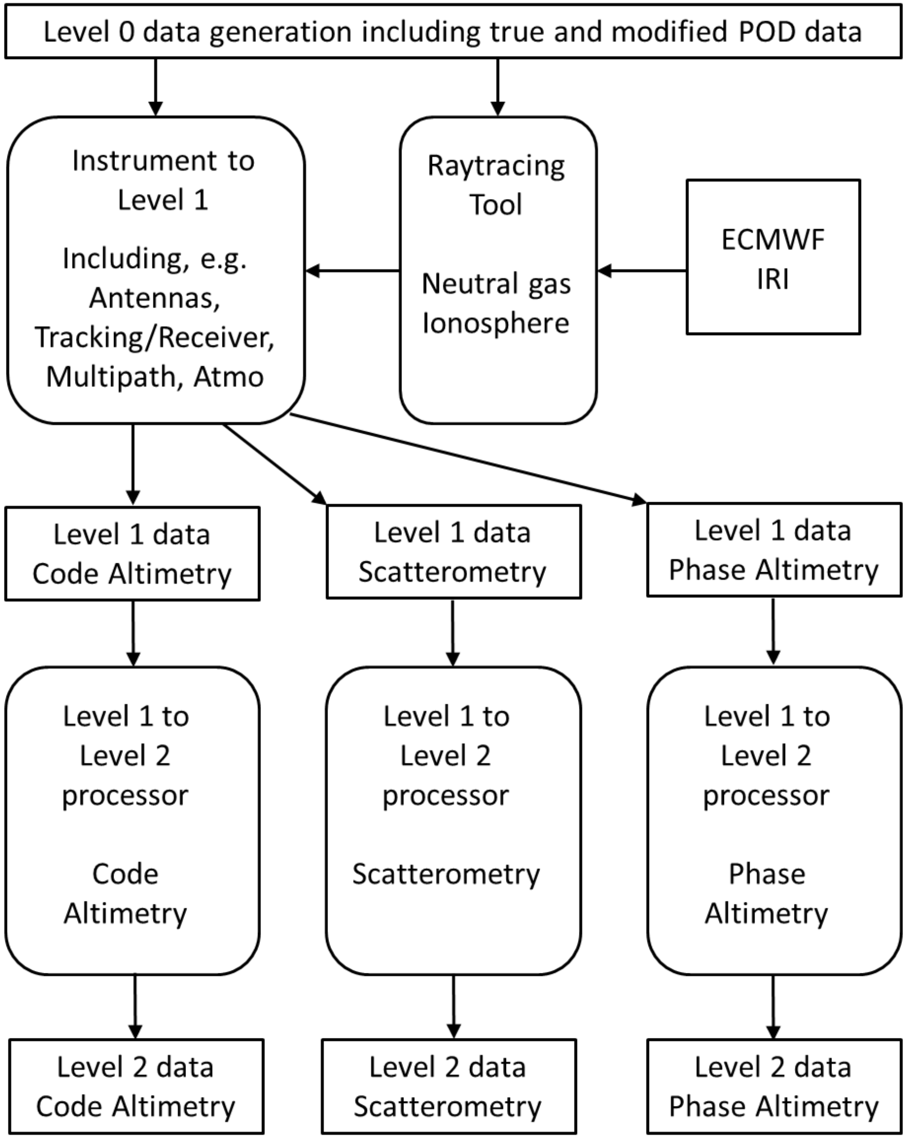


Climate change (2011)
Wickert et al., 2016

Earth Explorer-9 (2017)
Cardellach et al., 2018

Main mission goals related to precise altimetry ocean/ice

GARCA: GEROS-SIM



Instrument parameters, GNSS-R observables (Level 1) and geophysical observables (Level 2)

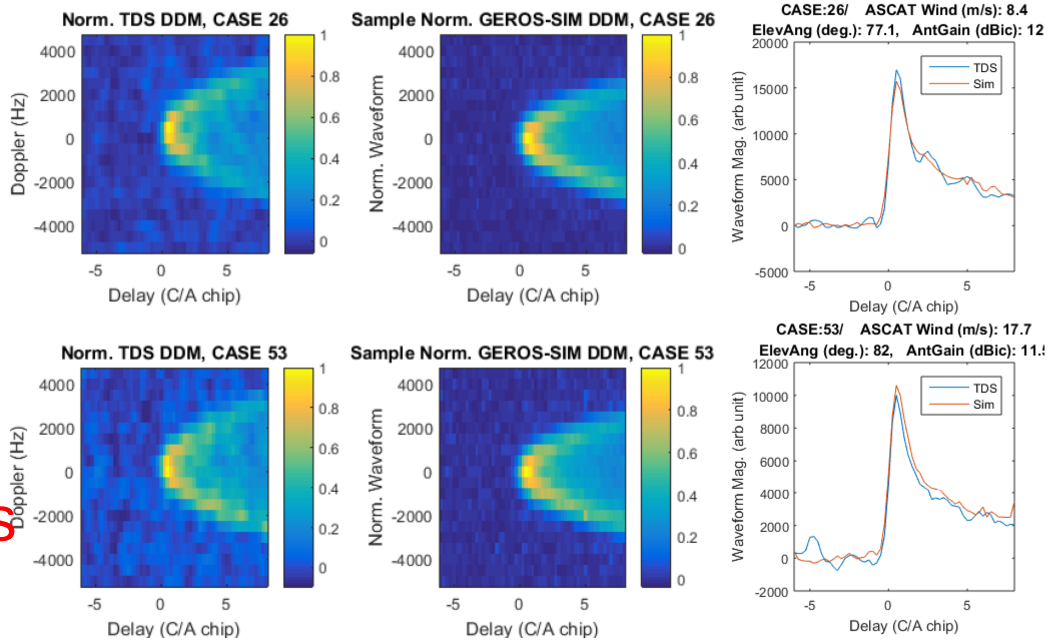
Core: PAU/PARIS
E2E Performance Simulator
IEEC

+ three Level 2 processors (Code & Phase altimetry, scatterometry)
IEEC, NOC, GFZ

GEROS-SIM: Code Altimetry

Wind
8.4 m/s

Wind
17.7 m/s



GEROS-SIM tested with real TDS-1 data and compared with simulated GEROS interferometric approach
Different wind speeds assumed

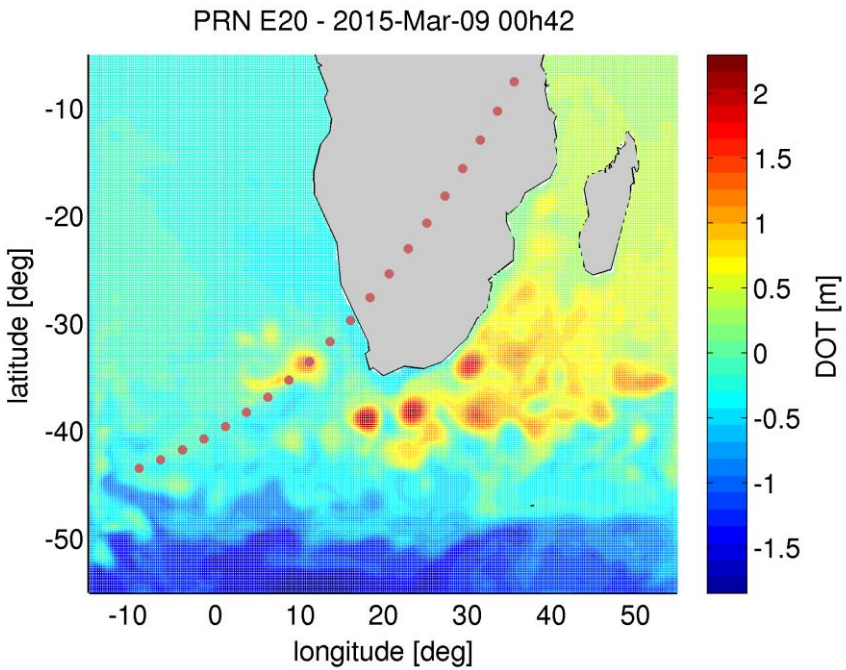
Integration time:	Along-track resolution:	Across-track resolution:	Precision figure:
L5 with 'clean' ionospheric correction			
1 second	7.5 km	4 km	11.3 cm
14 seconds	100 km	4 km	3.0 cm

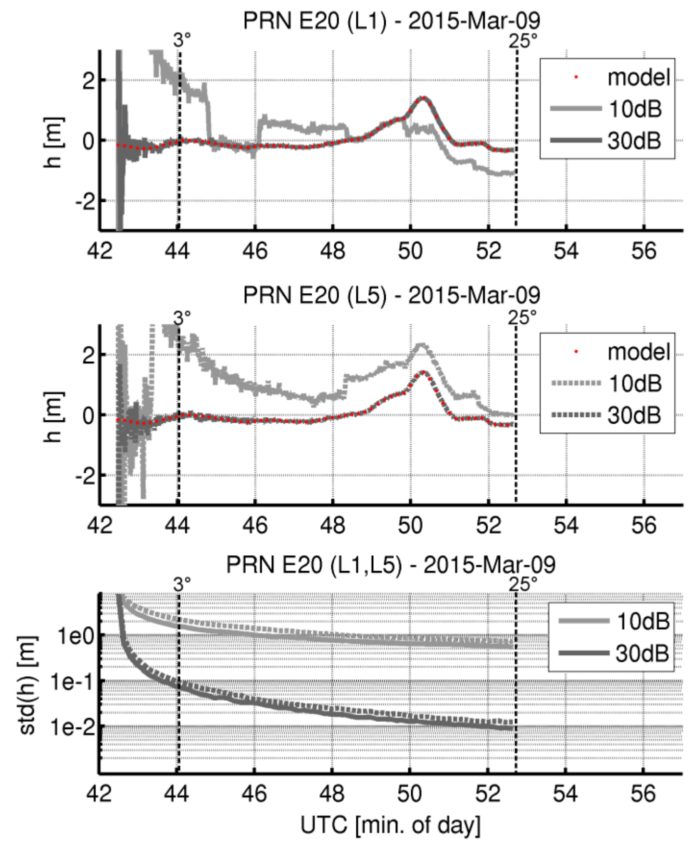
precision
3.0 cm

Estimated precision is well within key Mission requirement (see TN-4)

GEROS-SIM: Phase Altimetry

SSH reconstructions (L1,L5)





Ground track for the ISS example event in Agulhas region (left)
Retrieved SSH and precision estimate for different SNR (right)
Precision (1s, 7.5/0.5km along/across-track: **0.11 m** (30 db, 5 cm POD)

OSSE in South China Sea during Typhoon Rammsun

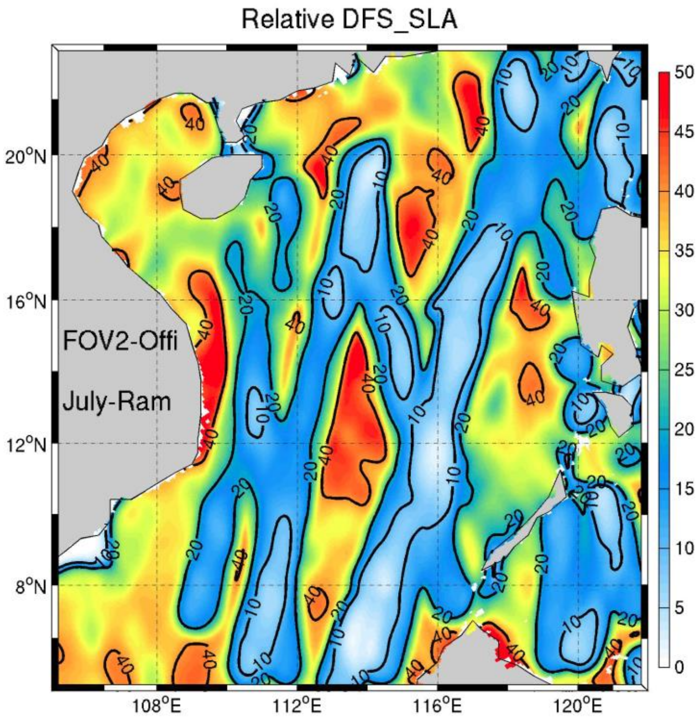
NERSC, Norway

Three months of assimilation of simulated GNSS-R data in the model and data assimilation system with HYCOM model (5 km) on top of the operationally used Radar-Satellite data (4) also during typhoon period in July 2014

Simulated observations
Three experiments:
* GEROS-ISS (limited FoV)
* Free Flyer FoV-1 (Jason like)
* Free Flyer FoV-2 (Jason like)

Assumed errors (precision):
25 cm (10 km)

Xie/Bertino et al. (NERSC, 2017)



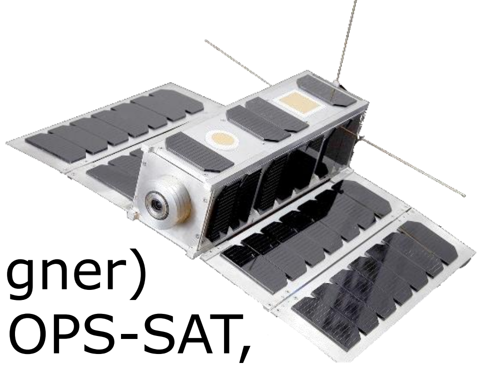
One example: (TN-5 GARCA)
Improvement of SLA reconstruction with GNSS-R F-FoV2 compared to use of traditional altimetry satellite data only
up to 50%
(for GEROS up to 20%)

PRETTY

Passive **RE**flec**T**ome**T**r**Y**

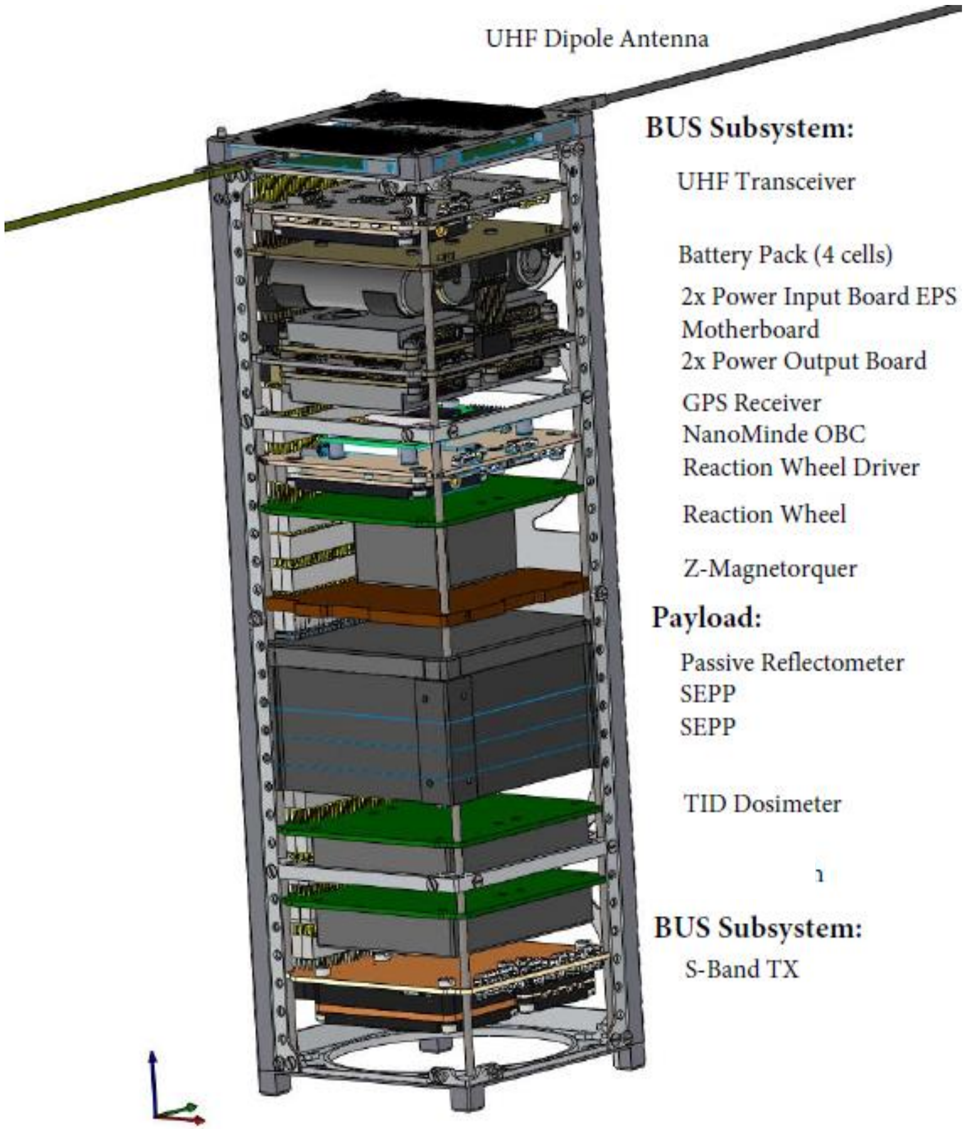
A cubesat for GNSS phase altimetry
and Space Weather research

Overview and status



- ESA small satellite mission
- Austrian consortium, led by RUAG GmbH (H. Fragner)
  relying on results from former ESA mission OPS-SAT, conducted by TU Graz
- Cubesat 10*10*30 cm
- GNSS-Reflectometry at low elevations (5-15°) with phase altimetric approach (direct/reflected with same RHCP); ~10 cm precision demonstrated with 1s observations
- Software-Defined-Radio front-end is Myriad RF-1 COTS board based on LMS6002D transceiver IC by Lime Microsystems
- Antenna: 6 patches; gain 15 db/half-power beamwidth 25,5°
- Technical and scientific activities for Phase A/B are in definition, recently proposal for science support by IEEC, UoO, GFZ
- Launch foreseen for 2021

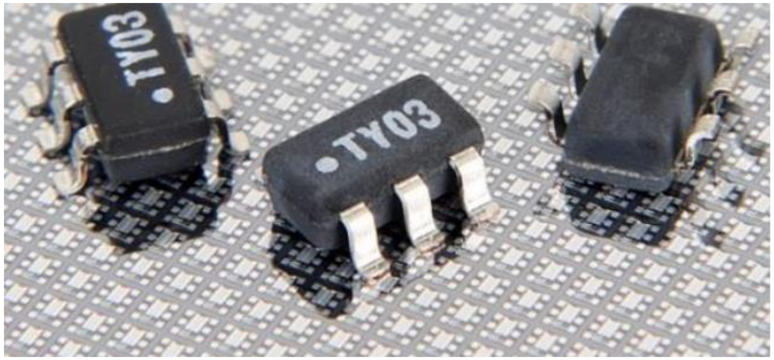
PRETTY subsystem arrangement



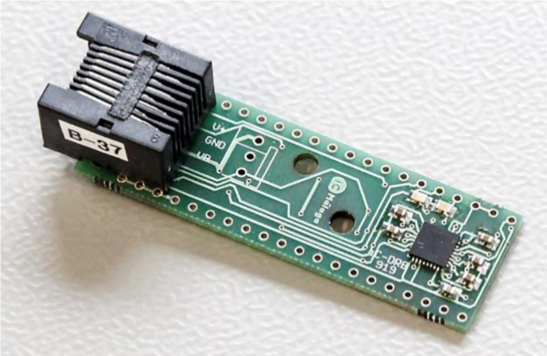
Space Weather Payload

Total ionizing dose measurements

RadFET Dosimeter



FloatingGate Dosimeter



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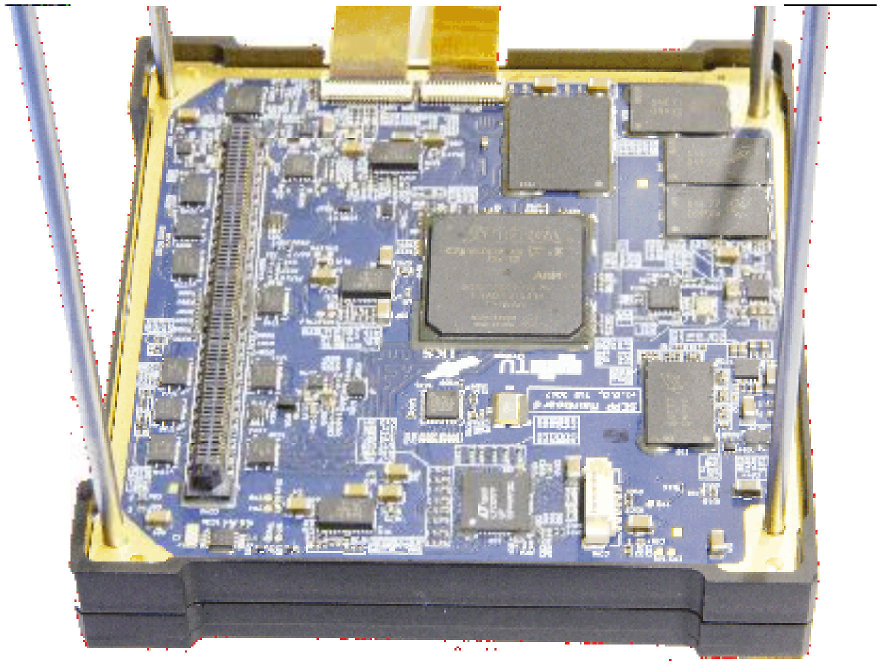
Individual particle detection

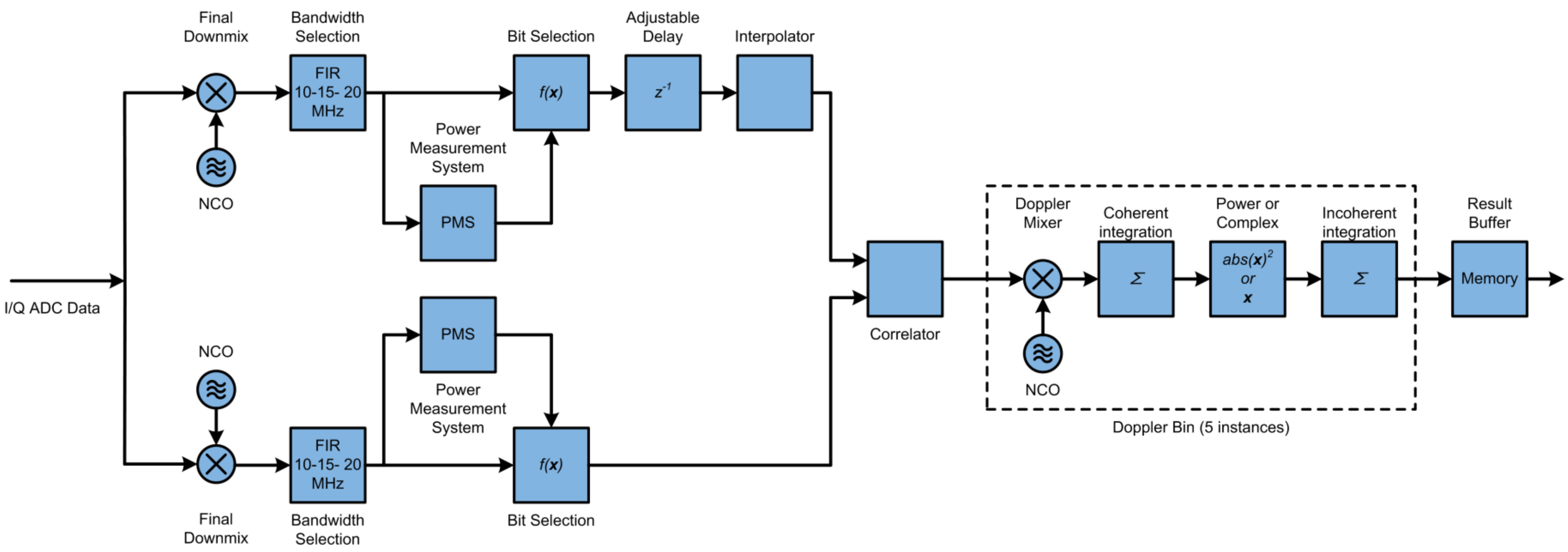
Linear Energy Transfer (LET) Spectrometer

Satellite Experimental Payload Platform (SEPP)



- FPGA with Dual-Core ARM processor, providing resources for PACO unit.
- GNSS-R control software for observation steering including GNSS data and onboard ORBIT solution
- Software Defined Radio (SDR) Front end is on a separate PCB (Printed Circu Board) for down-conversion of L1 signal and analogue to digital conversion

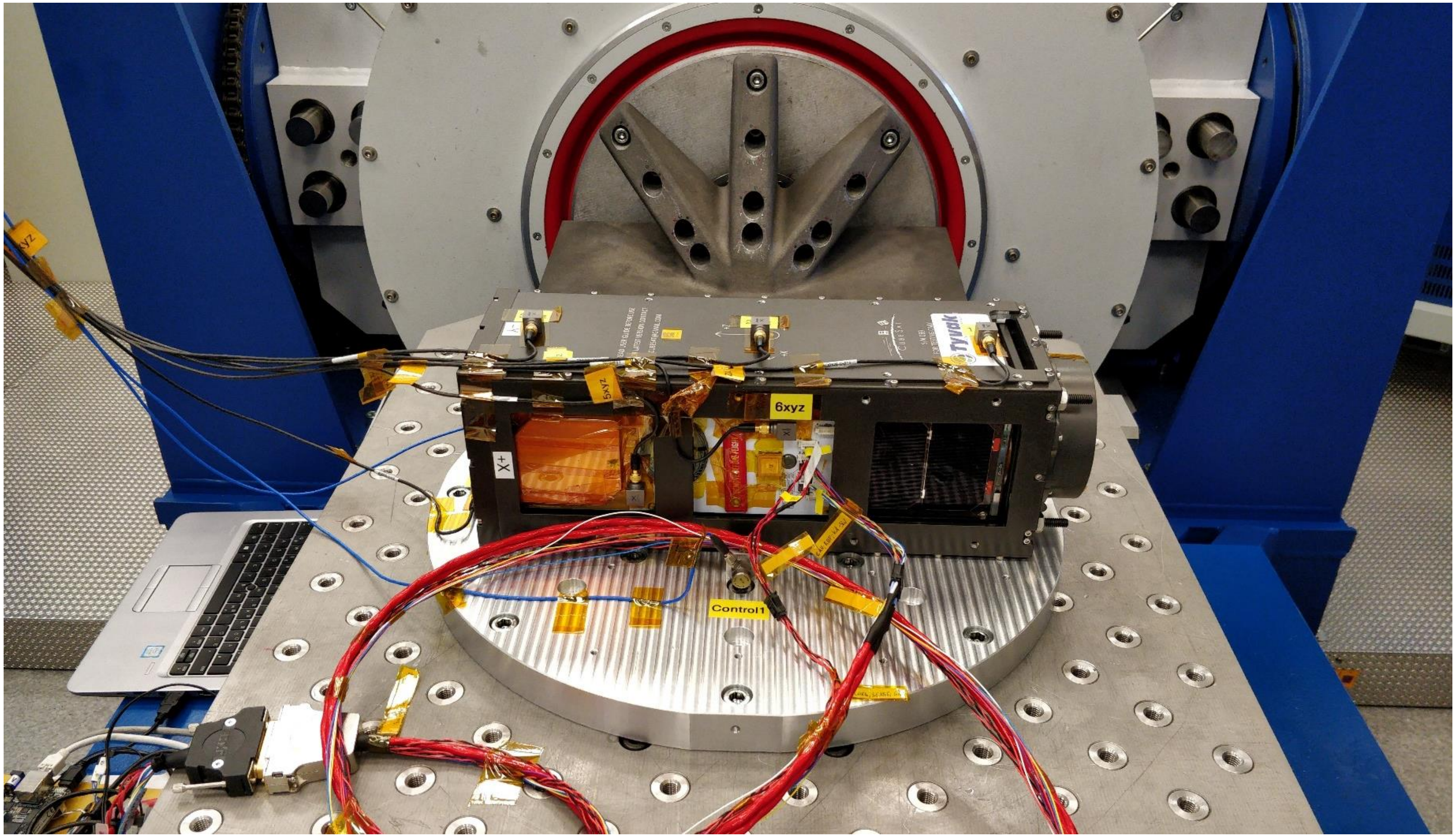
PARIS Correlator (PACO), adapted within PACube study (PACO for CubeSat)



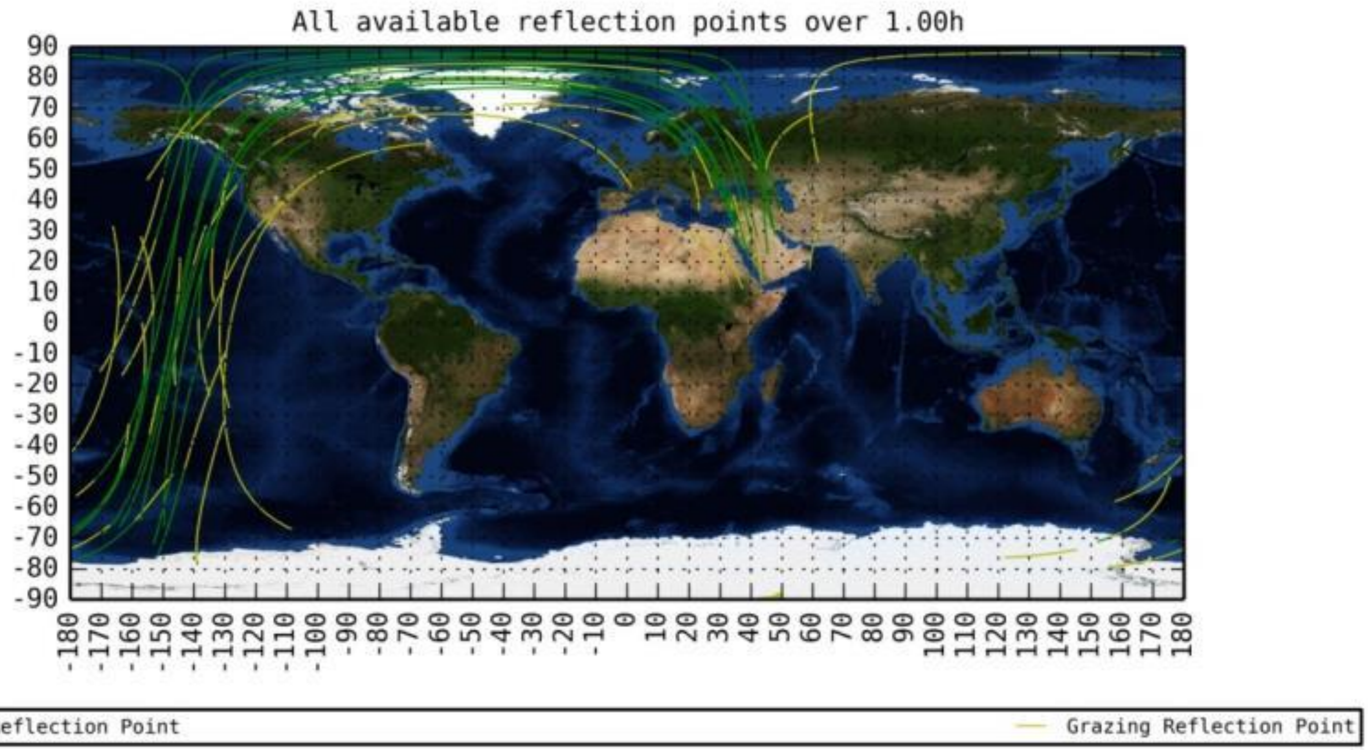
GNSS-R antenna array

8 segments, L1, RHCP, max. gain 16,3 db

Satellite test at TU Graz (OPS-SAT heritage TUG/ESA)



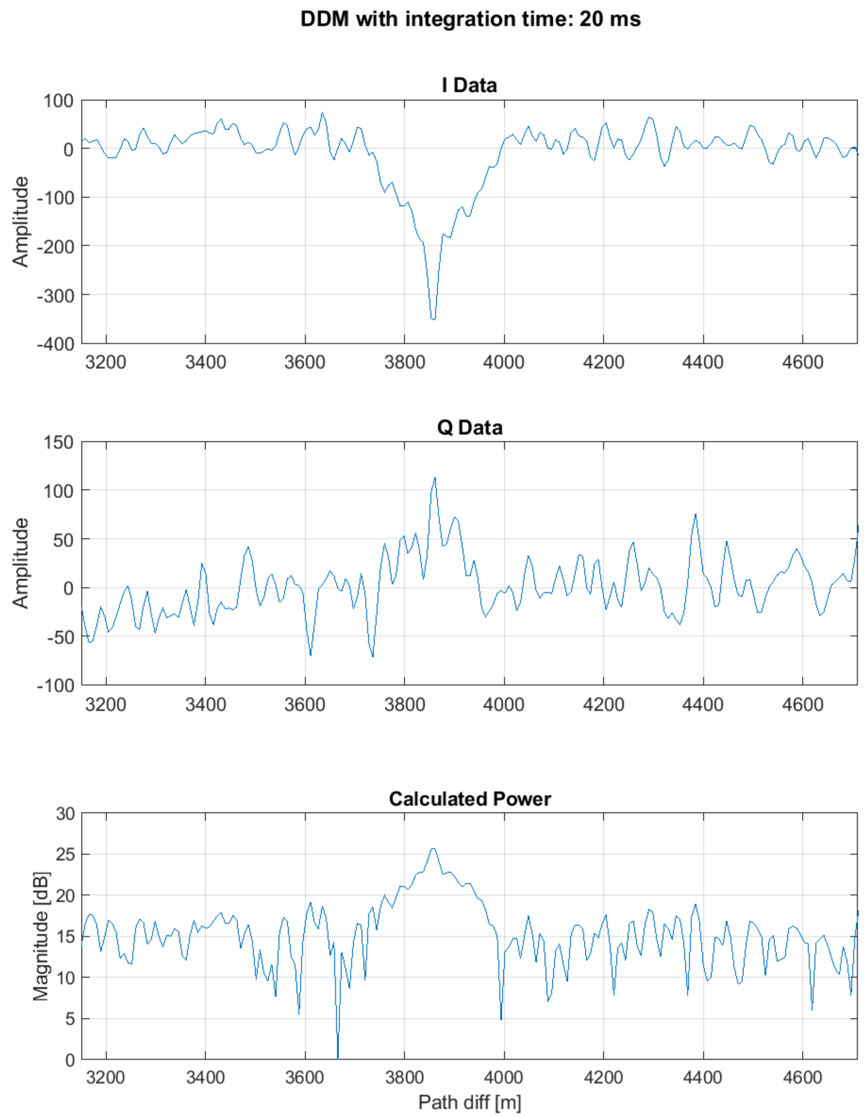
Simulated PRETTY Reflection points



- Limitations for duty cycle (<30%)
- Measurements during eclipse (ionosphere)
- Orbit altitude ~550 km, ground operation TU Graz

Signal simulator test

Reflection with ~3.8 km path difference



Summary

- Some information on history on grazing altimetry at GFZ was given, started within the CHAMP mission and strongly supported as part of the GITEWS project
- This concept in parallel with interferometriy GNSS-R was also part of the GEROS-ISS and G-TERN concepts
- The ESA small satellite mission PRETTY was briefly introduced, application of grazing altimetry between 5 and 15^{o} based on interferometric GNSS-R is one of the two main science goals, beside Space Weather research
- Initial spaceborne data are expected for 2021

Grazie!